1904 June 17. There was a heavy, diffused, broad dark belt north of the equator.

1904 July 2. The north belt was very heavy and diffused.

1904 July 4. The north belt was heavy and broad.

1904 July 11. The north polar region was of a light yellow colour.

1904 August 27. The north polar region was light-coloured.

1904 December 5. Light at the equator, with broad dusky region toward the north, but all the north region was lighter.

I have purposely withheld (for another paper) the observations of Saturn in 1903, at the time of the appearance of the white spot on the ball of the planet.

Unless otherwise stated, all the observations in these papers were made with the 40-inch telescope.

Yerkes Observatory,
Williams Bay, Wis.:
1908 *January.*

Photometric Measurements of Saturn, August to December 1907.

By J. M. Baldwin, M.A., 1851 Exhibition Scholar (Melbourne).

(*Communicated by Sir David Gill.*)

During the recent opposition of Saturn, at the suggestion of Professor Müller, I undertook a series of photometric measures of that planet. This opposition has been of particular interest, for, owing to the small elevation of the Earth above the plane of the ring, the reduction to "ring invisible" is subject to very slight uncertainty, and so the variation in the brightness of the spheroid itself with phase angle can be obtained.

Seeliger * has theoretically arrived at an expression for the magnitude of Saturn, in which the magnitude depends on two quantities, the first of which, expressing the light received from the ring, shows a marked variation with phase, while the second, expressing the light from the spheroid, is almost independent of phase. Müller,† on the other hand, has arrived at empirical formulæ for the magnitude, in which the variation in magnitude is proportional to the change in phase. In discussing his observations and those of Zöllner, he remarks (*l.c.*, p. 343), "es scheint also, als ob auch bei gänzlich verschwundenem Ring ein Einfluss der Phase sich geltend mache"; and Pannekoek ‡ has further emphasised this point, showing that the observed change of brightness with phase when the elevation of the Earth above

* H. Seeliger, *Abhandl. der Bayer. Akad. der Wissensch.*, Bd. 16, 403, 1888.

† G. Müller, *Publ. des Astrophys. Observ. zu Potsdam* 8, 339 u. 341, 1893.

‡ Ant. Pannekoek, *Ast. Nach.* 4006, Bd. 167, 363, 1905.

the plane of the ring was small are greater than accounted for by Seeliger's theory, and so rendering it probable that the spheroid itself shows changes in brightness with the phase. The object of this series of measurements was therefore to determine which of the two formulæ agreed best with observation.

In order to avoid bias, I was careful not to find out the magnitudes of the variation in phase given by the formulæ; and further, the observations were not reduced at all until after the whole series was completed.

The instrument used throughout was the Zöllner photometer referred to in the Potsdam publications as C III, the objective of which is of 21·5 mm. aperture and 137 mm. focal length. (For description see *Publ. Astr. Obs. zu Potsdam*, Bd. viii., p 17, 1891.) In this instrument the image of the planet differs but little from that of a star. Unfortunately there was no suitable comparison star near Saturn; α Aquilæ, distant some 60°, was chosen as the most convenient and was used throughout. Its magnitude has been taken as 0·96 (*l.c.*, p. 235), so that Saturn should be referred to the same system as former planetary observations here have been. For the extinction correction the mean values for Potsdam have been used.

A typical set of observations and the method of reduction is shown in Table I.

TABLE I.

1907 Sept. 24.	Potsdam Sid. Time.	Quadrant. I.	II.	III.	IV.	Mean I.	Log sin² I.	$\frac{d \log}{\sin^2 I.}$	Zenith Extinction. Dist.	Corr.	ΔM.
	h m	°	°	°	°	°			°		
Saturn	23 12	29·1	24·9	29·4	30·5	28·47	9·3566	+111	57·5	+199	+·08
α Aquilæ	17	31·9	26·0	28·7	28·9	28·87	9·3677	...	61·0	...	...
α Aquilæ	19	29·4	24·1	32·8	26·3	28·15	9·3475	...	61·3	...	...
Saturn	22	28·0	26·9	27·3	30·0	28·05	9·3446	+ 29	57·3	+229	+·06
Saturn	25	30·9	27·0	32.8	27·6	29·57	9·3867	−428	57·3	+324	−·03
α Aquilæ	29	27·1	26·1	30·9	28·0	28·02	9·3439	...	62·7	...	...
α Aquilæ	33	30·4	26·1	27·3	27·2	27·75	9·3360	...	63·3	...	...
Saturn	36	32·2	26·1	29·0	29·0	29·07	9·3732	−372	57·2	+372	·00

In a few cases, however, only eight readings for each were taken, and occasionally α Aquilæ was observed first.

The results of the observations are given in Table II.

TABLE II.

	G.M.T.				Z_s.	Z_α.	ΔM.	Corr.	M_0.	a.	A.	A′.	M_M.	O—C.	M_s.	O—C.
		d	h	m	°	°				°	°	°				
1	Aug.	11	10	55	66·0	46·7	+0·22	−·04	1·14	3·77	−1·82	−0·23	0·96	+·18	0·93	+·21
2		14	11	4	63·8	48·1	+0·08	·03	1·01	3·52	1·74	0·27	0·95	+·06	0·93	+·08
3		16	10	30	66·7	46·3	+0·37	·03	1·30	3·34	1·69	0·30	0·95	+·35	0·93	+·37
4		20	10	45	63·4	48·7	+0·08	·02	1·02	2·97	1·56	0·36	0·94	+·08	0·93	+·09
5	Sept.	4	10	30	59·9	53·1	+0·12	·01	1·07	1·46	1·05	0·59	0·89	+·18	0·92	+·15
6	Sept.	10	11	2	57·3	59·9	+0·13	−·01	1·08	0·83	−0·83	−0·68	0·88	+·20	0·92	+·16
7		11	10	29	58·4	56·1	+0·06	·01	1·01	0·73	0·79	0·69	0·87	+·14	0·92	+·09
8		12	10	20	58·6	55·6	−0·02	·01	0·93	0·63	0·76	0·71	0·87	+·06	0·92	+·01
9		13	10	56	57·2	60·8	+0·02	·01	0·97	0·53	0·72	0·72	0·87	+·10	0·92	+·05
10		18	10	31	57·3	60·1	−0·01	·01	0·94	0·28	0·53	0·80	0·86	+·08	0·92	+·02
11	Sept.	22	10	7	57·8	59·0	+0·02	−·01	0·97	0·59	−0·39	−0·86	0·89	+·08	0·92	+·05
12		24	10	21	57·3	62·1	+0·03	·01	0·98	0·80	0·32	0·89	0·90	+·08	0·92	+·06
13		25	9	52	57·9	58·6	−0·09	·01	0·86	0·90	0·28	0·90	0·90	−·04	0·92	−·06
14		27	10	5	57·5	61·4	−0·04	·01	0·91	1·11	0·21	0·93	0·92	−·01	0·93	−·02
15		28	9	2	59·8	53·6	−0·04	·01	0·91	1·21	0·17	0·95	0·92	−·01	0·93	−·02
16	Sept.	29	9	29	58·3	57·6	−0·10	−·01	0·85	1·32	−0·14	−0·96	0·93	−·08	0·93	−·08
17	Oct.	2	9	27	58·0	58·8	+0·02	·01	0·97	1·63	0·04	1·01	0·95	+·02	0·93	+·04
18		3	9	17	58·2	58·1	0·00	·01	0·95	1·74	0·00	1·02	0·95	·00	0·93	+·02
19		8	9	27	57·7	62·1	+0·13	·02	1·07	2·25	+0·16	1·10	0·97	+·10	0·93	+·14
20		11	8	51	58·2	58·8	−0·04	·02	0·90	2·55	0·25	1·14	0·98	−·08	0·92	−·02
21	Oct.	20	8	51	57·9	63·6	+0·16	−·03	1·09	3·39	+0·50	−1·27	1·00	+·09	0·92	+·17
22		24	8	48	58·1	65·5	+0·01	·03	0·94	3·74	0·59	1·33	1·01	−·07	0·92	+·02
23	Nov.	3	8	23	58·5	67·4	+0·19	·05	1·10	4·51	0·77	1·48	1·04	+·06	0·92	+·18
24		27	6	2	58·3	61·0	+0·20	·09	1·07	5·69	0·90	1·84	1·08	−·01	0·91	+·16
25	Dec.	1	4	57	59·7	54·3	+0·13	·09	1·00	5·78	0·87	1·90	1·09	−·09	0·91	+·09

1. Hazy near horizon.
2. Only eight observations of each. Wt. ½.
3. Seeing good; at times cloudy in parts. Wt. ½.
10. Only eight observations of each. Clouded over suddenly. Wt. ½.
11. Light cloud visible near moon.
14. Slightly foggy. Wt. ½.
16. Cloud rising slowly below *α* Aquilæ. Wt. ½.
18. Eight observations; seeing below *α* Aquilæ bad. Wt. ½.
21. Somewhat foggy; cloud rising below *α* Aquilæ. Wt. ½.
22. Seeing not good, especially below *α* Aquilæ. Wt. ½.
23. *α* Aquilæ very unsteady.

In Table II., Z_s and Z_a are the zenith distances of Saturn and α Aquilæ respectively for the mean time of observation; ΔM is the observed difference of magnitude (Saturn—α Aquilæ) corrected for extinction; the next column contains the correction to mean opposition, and M_0 is the magnitude for mean opposition; α is the phase angle; A the elevation of the Earth; A′ that of the Sun above the plane of the ring; M_M and M_s are the magnitudes calculated from the formulæ of Müller and Seeliger, in each case using Müller's values for the constants (*l.c.*, pp. 339, 341, and 348); and O—C are the values of M_0—M_M and M_0—M_s respectively.

On examining the column M_0 it is seen that the early observations are irregular; this is probably due to a large extent to want of practice with the instrument, these being the first observations that I had made with it, although I had been using another Zöllner photometer (photometer D) for stellar work for some months. The irregularity may also arise partly from uncertainty in the extinction correction in the first four observations, where the difference in zenith distance is so large (15 to 20 degrees). If the night were not very clear, the difference in extinction would be greater than that given by the Potsdam tables, the values of ΔM would be diminished, and the observed values would agree better with the computed. On account of this irregularity I give the results deduced

(1) from all the observations,
(2) from the observations after opposition (Nos. 10–25),

the conclusions for the latter being, in my opinion, more reliable than from the whole series.

From Table II. it appears—

(1) That if Seeliger's formula were true, the magnitude of Saturn during the observations would be almost constant, becoming very slightly brighter towards the end of the series. The observations, on the other hand, show that the brightness reduced to mean opposition shows a decided decrease after opposition, and so Seeliger's formula cannot hold. If Seeliger's second formula (*l.c.*, p. 489), which assumes a different law for emanation, be used, the results obtained are almost the same, the difference being slightly more marked.

(2) On the other hand, although the earlier observations of the series do not agree well with the results deduced from Müller's formula, yet those after opposition show a very satisfactory agreement. From the column O—C, giving the weight $\frac{1}{2}$ to certain observations as indicated in the table, the mean error is

(*a*) for all observations $\pm 0{\cdot}115$ mag.
(*b*) for Nos. 10–25 $\pm 0{\cdot}069$ „

If the reduction to "ring invisible" is applied to the mean opposition magnitude (this reduction is $+{\cdot}081$ on August 11,

·000 on October 3, and + ·040 on November 27), and the results substituted in the formula

$$h = h_0 + a\alpha,$$

the values for the constants h_0 and a determined by the method of least squares are

(*a*) for all observations $h_0 = 0{\cdot}967$, $a = {\cdot}0300$, mean error of $h \pm {\cdot}095$
(*b*) Nos. 10–25 $h_0 = 0{\cdot}916$, $a = {\cdot}0313$, mean error of $h \pm {\cdot}064$
while Müller's values are $h_0 = 0{\cdot}877$, $a = {\cdot}0436$.

As before stated, the second set of values for h_0 and a are probably much more reliable than the first set.

It appears then from the observations that the spheroid of Saturn shows a change of brightness with phase, and the change in magnitude can be well represented by the formula

$$h = 0{\cdot}877 + {\cdot}0436\alpha$$

already obtained by Müller from his long series of observations.

Astrophysical Observatory, Potsdam:
1908 Jan. 24.

Reappearance of Saturn's Ring, January 1908.
By R. T. A. Innes.

The following observations of the ghost-ring and of the reappearance of the ring were made here with the 9-inch refractor.

1907 Dec. 25. Ghost-ring seen on both sides, but more distinct on *f.* side. Shadow of ring quite its own breadth N. of equator and very black—no longer brown.

Dec. 28. Ring-like extension very faint, is more distinct on *f.* side—is to S. of shadow.

Dec. 29 and 30. Ghost-ring still visible.

Dec. 31. Just glimpsed (ghost-ring)—4 satellites seen close to Saturn.

1908 Jan. 3. Ghost-ring invisible—Mimas or Enceladus at *p.* elongation.

Jan. 4. No ghost-ring seen.

Jan. 5. No trace of ring-system—one satellite about 4″ and another about 10″ *f.* Saturn—the nearer of these would be half way along the ring had the latter been visible.

Jan. 6. $5^h\ 30^m$ to $6^h\ 5^m$ G.M.T. Ring shadow appreciably narrower—no trace of ring.

Jan. 7. $6^h\ 20^m$ G.M.T. Bad definition through passing thunderclouds. No trace of ring—two satellites, much closer in than Titan, seen closely *f.* Ring shadow narrow.

Jan. 8. $5^h\ 35^m$ G.M.T. (daylight). Ring visible—it is very fine, and not unlike the ghost-ring of a month ago. From my recollection of the disappearance in October 1907, the ring looks as though it had reappeared about six hours earlier. The ring is brighter *f.* the planet—this was verified by using the erecting eye-